

**Application of the Analytical Hierarchy Process to evaluate consumer acceptance and preferences
for omega-3 enriched eggs.**

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Structured abstract

Purpose

This paper analyses the appropriateness of the Analytical Hierarchy Process (AHP) to measure consumers' acceptance and preference for eggs enriched with omega-3 (n-3) fatty acids as a health claim and to compare its results with the traditional 9-point hedonic scale.

Design/methodology/approach

The AHP was used as a multi-criteria decision analysis. Data were obtained from a face-to-face questionnaire completed by 122 consumers in a controlled environment in Cataluña (Spain).

Findings

Results showed the capacity of the AHP to analyse consumers' acceptance and preferences. An agreement between the AHP and the 9-point scale was found showing that n-3 enriched eggs had lower flavour acceptance, conventional eggs had higher yolk colour acceptance, and conventional and the free-range eggs had similar and higher odour acceptance than the other egg types. The most important attributes that determine preferences for egg purchase were the type and the egg price followed by the origin and the egg size.

Research limitations/implications

The AHP approach seems to be a reliable tool to evaluate consumers' hedonic preferences. However, further testing on other food products with larger sample size is needed.

Originality/value

The AHP methodology has been widely used in many fields in the last decades, but to our knowledge, not in the sensory field. In the Spanish market, studies that analyse consumers' preferences and acceptance of eggs are scarce, and new insights are needed particularly regarding n-3 enriched eggs.

Keywords: AHP, 9-point hedonic scale, consumers' acceptance, consumers' preference, eggs, n-3.

1. Introduction

Different sensory evaluation techniques are available and the selection of the suitable method depends greatly on the main objective of the research. On one side, if the aim is to indicate whether the difference is perceived among food products or to describe and estimate differences in size, specific protocols are used. In this case, the panellists are formed by trained judges. On the other side, if the aim is to analyse consumers' acceptance and preference to estimate the level of likeness of food products, the hedonic sensory protocols are usually applied. In this case, the panellist sample is usually formed by non-trained consumers which are stratified by age, gender or other socio-demographic variables.

The comparative methods are one of the relevant techniques to estimate differences among products (Meilgaard *et al.*, 2006). Difference tests are the most accepted and simplest way of product testing (Lim, 2011). They are used to determine differences in some specific descriptors between two or more samples, and are also applied to test if a product in its holistic evaluation is preferred to others. Several sensory discriminative protocols can be found in the sensory literature (Kim *et al.*, 2015). The most commonly used in the empirical applications for food products are the 2-AFC, 3-AFC, triangle, and the duo-trio methods among others. The 2-AFC and the 3-AFC are directional techniques that require specific attributes in testing differences between products. The triangle and the duo-trio methods are non-directional because they test un-specified differences (Christensen, 2015). Data in these protocols are analysed by estimating the percentage of correct responses or the probability of discrimination.

For consumer acceptance and preference studies, pairwise and ranking approaches can be used. Following the former, consumers are asked to state the product they prefer or like the most from two products. For the latter approach, consumers are asked to rank more than two

products from the most to the least preferred. Furthermore, the traditional hedonic evaluation approach can be also applied using the most accepted 9-point hedonic-scale of likeness.

The 9-point hedonic scale is one of the most used (Lim, 2011) scales when carrying out hedonic evaluations for food products, mainly due to its reliability and discriminability (Peryam and Pilgrim, 1957). As originally defined, this scale is a balanced bipolar around a neutral center with four positive and four negative categories on each side. It is easy to apply and highly heterogeneous participants can respond meaningfully to it without prior experience (Peryam and Girardot, 1952). Furthermore, data obtained can be handled by parametric methods allowing to estimate levels of preferences. The commonly used verbal anchors of the scale as commented by Jones *et al.* (1955) are: like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely. Peryam and Pilgrim (1957), Moskowitz (1980) and Lim *et al.* (2009) mentioned that the psychological distances between the semantic labels on the 9-point hedonic scale are not equal and data are usually treated as continuous instead of categorical ordinal data. Nevertheless, the categories used may not reflect differences in perception and the presence of extreme categories lead participants to effectively use only 7 points of the scale (Villanueva and Da Silva, 2009). In all cases, there is a consensus in the sensory and consumer field that the 9-point scale can be safely used as continuous data for the analysis of consumer hedonic responses. Peryam and Pilgrim (1957) stated that labels' variations had "no major effect" on the results.

The Analytical Hierarchy Process (AHP) is a multi-criteria decision analysis method (MCDA) that can be proposed as a discriminative technique and a valid method to analyse consumers' acceptance and preference. This methodology has been widely used in many fields in the last decades. It was applied in environmental valuation (Govindan *et al.*, 2015), in agriculture management (Giri and Nejadhashemi, 2014), in technology adoption (Nikou

and Mezei, 2013), in credit assessments (Gutiérrez-Nieto *et al.*, 2016), in public policies evaluation (Brent *et al.*, 2007), in decomposing food product value (Kallas and Gil, 2012) among other areas and research applications. However, to our knowledge, the AHP has not been used yet in the sensory field. This paper, up to date, is the first application of the AHP to analyse consumers' acceptance in order to test for differences among products on the basis of their characteristics and attributes.

The AHP method relies on mathematics and psychology and aims to organize and analyse complex decisions (Saaty, 1980). It is based on decomposing the product into a hierarchy of their attributes or descriptors. On one hand, the AHP is able to analyse consumers' acceptance through the hedonic evaluation of sensory attributes, and on the other hand, this technique also allows studying consumers' preference for non-sensory descriptors. Both approaches may help researchers to understand the willingness to accept and purchase food products. In this line, consumers' acceptance is highly relevant and may have an influence on consumers' willingness to pay when studying food choices (Maehle *et al.*, 2015). Not only the intrinsic quality cues are determinant features affecting consumers' response, but also the extrinsic cues of the product (Ares, *et al.*, 2010). Thus, the hedonic and purchase intent ratings are both relevant to understand consumers' acceptance and preference of a product.

In this context, the main objectives of this research were twofold: First, at the methodological level, to test the appropriateness of the AHP as a valid technique in the analysis of consumers' acceptance and preference for chicken eggs enriched with omega-3 (n-3) fatty acids and to compare its results with the traditional 9-point hedonic scale. Second, at the empirical level, to evaluate the relative importance of egg attributes including its enrichment with n-3 fatty acids on purchasing decisions of Catalan consumers in Spain.

2. Materials and methods

2.1. Background and case study

Chicken eggs enriched with n-3 fatty acids were selected as a case study to analyse consumers' acceptance and preference by the AHP approach. Data were obtained from a face-to-face survey procedure completed in a controlled environment. The sample consisted of 122 consumers over 18 years of age who purchase food and beverages regularly and having purchased eggs in the last month. Participants were recruited through the Centre for Agro-food Economy and Development (CREDA). Consumers were seated in individual booths at the test lab of the Agriculture Engineering School of Barcelona (ESAB) according to the UNE-ISO 8589 (2010).

Analysing consumers' acceptance for n-3 enriched eggs is not new and has been studied decades ago (Adams *et al.*, 1989; Caston *et al.*, 1994; Scheideler *et al.*, 1997; Parpinello *et al.*, 2006 and Lawlor *et al.*, 2010). However, in the Spanish market, the analysis of consumers' preferences and acceptance of eggs, particularly those enriched with n-3 fatty acids, has not been explored. New insights are needed to update knowledge on actual consumers' preferences and acceptance. The selection of enriched eggs with n-3 fatty acids as an empirical application, was based on the increasing relative importance of introducing n-3 enrichment as a health claim in food products, and because this egg product has differentiated attributes.

Health claims are gaining prominence as key factors affecting the purchasing decision for food products and are becoming one of the most relevant predictors for food consumption (Lusk *et al.*, 2003). Food producers and marketers are continuously exploring new strategies for providing markets with healthier food products. In this context, according to our analysis of a Mintel data set (Mintel, 2015), the percentage of new launched food products with health claims in the Spanish market grew by 172.2% between 2010 and 2014. The proliferation of

these products has led the public authorities responsible for food policy to regularly control the appearance of these new claims. The list of allowed health claims in the EU is found in the annex of the Regulation 432/2012 (EC, 2012) which authorizes the use of 222 claims. The enrichment with n-3 fatty acids is identified within the category of ‘risk reduction claims’. Omega-3 fatty acids help on reducing the risk factor in the development of heart disease and also contribute to the maintenance of normal blood cholesterol levels.

The penetration in Spanish households of enriched eggs with n-3 fatty acids is very limited, which represents an opportunity for egg producers. Modifying the type of fat in eggs through modifications in the animal diet, would offer the consumer a fatty acid profile closer to the current nutritional recommendations for a healthy diet and would improve the nutritional image of eggs. Animal feeding strategies have been successfully used to significantly increase polyunsaturated fatty acids in eggs (Parpinello *et al.*, 2006; Lawlor *et al.*, 2010). The most common practice for producing n-3 fatty acid-modified eggs is by feeding flax seeds and fish oil to laying hens. Antioxidants are also added in order to minimize lipid oxidation (Qi and Sim, 1998).

2.2. Purchasing preferences

The first step consisted on a pre-sensory questionnaire (20 minutes) carried out to analyse factors affecting consumers’ decisions when purchasing eggs using the AHP. Consumers were asked to make pairwise comparisons between attributes and levels of those attributes that usually take into consideration in their decision when purchasing eggs. The relative importance of the attributes and their levels was then estimated following a hierarchy structure. The estimation procedure and the theoretical approach of the AHP are explained in section 2.4.

A key element for the application of the AHP is the identification of the attributes and their levels. The process of purchasing food products is complex in general and depends on a various number of cues that characterize the different products. Such complexity generates some difficulties when trying to determine the key factors that intervene in the consumer's decision making process. We identified various attributes from the literature that are usually taken into consideration when purchasing eggs, that were subsequently discussed in a non-formal focus group involving lecturers and researchers in the field of agro-food marketing as well as members of household associations in Catalonia.

Gracia *et al.* (2013) analysed the Spanish consumers' preferences when purchasing eggs. They used the egg price, the origin and the production method as the most relevant attributes. Mesías *et al.*, (2011) in another Spanish case study used the animal feed, if the eggs were enriched or not with n-3 fatty acids, the rearing conditions, the egg size and the price. Ness and Gerhardy (1994) focused on the freshness and quality of the eggs as determinant factors for purchasing eggs. They used the production method, the origin, the freshness information and the price. Norwood and Lusk (2011), focused on hen welfare aspects such as the barn space per hen and the beak trimming as potential attributes to infer animal welfare when taking purchasing decisions of eggs. Finally, the first attribute included in our experiment was the egg type with three levels: conventional, free-range and enhanced with n-3 eggs. By conventional eggs we refer to the traditional offer of eggs from battery-caged hens, with intensive feeding and production systems. By free-range eggs we refer to eggs from hens with improved animal welfare standards that are not reared in cages and have access to outdoor runs. By enhanced eggs with n-3 fatty acids we refer to eggs from battery-caged hens with intensive feeding enriched by flax seeds and fish oil (rich sources of n-3 fatty acids), and antioxidants to minimize lipid oxidation. The second attribute considered in the present study was the egg size with small, medium and large levels. The third attribute was the origin with

local, Catalan and other Spanish region levels, and the last attribute was the egg price. These identified egg descriptors and their levels were compared and their relative importance was estimated by the AHP procedure. An example of the pairwise comparisons of the attributes can be shown in Table 1.

It is worth mentioning that in order to minimize the hypothetical bias of the pre sensory-questionnaire a standard “*cheap talk*” procedure was included at the beginning of the test as proposed by Carlsson *et al.*, (2005) to motivate participants to state their real preferences as follows: “Previous studies indicate that individuals in general respond to surveys differently from the way they act in real life. It is quite common to find that individuals say they are willing to pay higher prices than those that they are really willing to pay or to select the products that are environmentally friendly or committed with animal welfare. We believe that this is due to the difficulty in calculating the exact impact of these higher expenses on the household economy or because we would prefer to be more committed with the environment, but we do not do it. It is easy to be generous when in reality one does not need to pay more”.

2.3. Sensory evaluation

The second step consisted on the evaluation of consumers’ acceptance towards three commercial types of eggs. Regular, free-range and enriched with n-3 eggs that were laid in the same day, were collected from the same farm. The eggs were purchased within two days of the sensory study and kept under refrigerated storage (4°C) for the duration of the experiment. We followed Parpinello *et al.* (2006) for the preparation of the different types of egg samples. Eggs were cooked in separate pots in boiling water for 8 minutes, using six eggs per treatment, and subsequently cooled them using running water to an external temperature of about 40°C. Next, they were shelled and divided longitudinally into 4 portions that contained

approximately a similar content of yolk. Samples were prepared without salt addition and the portions were covered by aluminium foil to preserve odour compounds.

Seven sensory sessions were conducted with approximately 15-20 consumers per session. Consumers evaluated in a blind condition, the acceptability of the three egg samples. They were presented with one plate of 3 samples coded with different 3-digit code in a balanced randomized order. Two different approaches were carried out for the hedonic sensory evaluation. On one side, the AHP technique was used by pairwise comparisons of the three products for each relevant sensory egg attribute. On the other side, a 9-point hedonic scale was also used to assess the same sensory attributes among the three types of eggs. Consumers in both cases were instructed to evaluate egg samples according to similarities or dissimilarities. Results were later statistically contrasted between the AHP technique and the 9-point hedonic scale.

For the hedonic evaluation of the eggs, we defined the main sensory attributes and levels to be included. We relied on prior research to identify the most used attributes in egg sensory studies (Sheideler *et al.*, 1997; Parpinello *et al.*, 2006; Sedoski *et al.*, 2012; Caston *et al.*, 1994; Lawlor *et al.*, 2010). The selected attributes were: egg odour, yolk colour and egg flavour.

For the hedonic scale application, levels were defined for egg odour (from 1: non-typical egg odour to 9: typical egg odour), yolk colour of eggs (from 1: non-typical yolk colour to 9: typical yolk colour), egg flavour (from 1: non-typical egg flavour to 9: typical egg flavour), and for global acceptance of eggs (from 1: dislike extremely to 9: like extremely).

In the case of the AHP application, pairwise comparisons between the three egg types were applied for the same sensory attributes. Respondents were asked to indicate which of the two compared egg types better fit the different sensory attributes using a 9-point scale proposed and validated by Saaty (1980) to measure the strength of the attribute description by

means of verbal judgments ranging from 1 to 9 where; “1” means that the sensory attribute has the “same” intensity in describing one egg compared to another one, “3” means that the sensory attribute has a “slight” intensity in describing one egg compared to another one, “5” that the sensory attribute has a “moderate” intensity in describing one egg compared to another one, “7” that the sensory attribute has a “strong” intensity in describing one egg compared to another one, and “9” means that the sensory attribute has an “absolute” intensity in one egg compared to another one. The values “2”, “4”, “6” and “8” are intermediate scores between the two adjacent judgments (Saaty, 1980). An example of the pairwise comparisons between the three types of eggs for the flavour attribute is shown in Table 2.

To mitigate the order effect, we followed a design based on ordering change between techniques (i.e. the sensory AHP and the sensory hedonic scale). We used a quota sampling procedure by allocating 50% of the sample to start with the AHP and the other half with the hedonic scale. In all other aspects, such as wording of questionnaire, the two versions were identical.

2.4. The Analytical Hierarchy Process technique

The basic idea of the AHP is to analyse individuals’ preference for the attributes and their levels of a product by eliciting the relative importance (w) through pairwise comparisons. In a survey, participants are asked to carry out all possible one way pairwise comparisons between attributes and between levels obtaining their weights (w_{A_m} , $w_{L_{m,n}}$ respectively) where; m ($1, \dots, M$) is the number of attributes and n ($=1, \dots, N$) is the number of levels of each attribute. In addition, pairwise comparisons may be also carried out between the products s ($= 1, \dots, S$) to analyse how a specific attribute m or level n describe two or more products s .

From the answers of the pairwise comparisons, a matrix with the following structure can be generated for each individual k (1, ... , K). This matrix is known as Saaty matrix (Saaty, 1980):

$$S_k = \begin{bmatrix} a_{11k} & a_{12k} & \dots & a_{1jk} \\ a_{21k} & a_{22k} & \dots & a_{2jk} \\ \dots & \dots & a_{ijk} & \dots \\ a_{i1k} & a_{i2k} & \dots & a_{NNk} \end{bmatrix} \quad (1)$$

where a_{ijk} (the judgments) represent the value obtained from the pairwise comparisons between attribute/level/product i ($i \in M / i \in N / i \in S$) and attribute/level/product j ; ($j \in M / j \in N / i \in S$) for each individual k . The fundamental properties of this comparison matrix are: a) reciprocal comparison: if $a_{ijk}=x$ then $a_{jik}=1/x$; b) homogeneity: if the element i and j are judged, they have an equal relative importance, thus, $a_{ijk} = a_{jik} = 1$; and c) all the elements of its main diagonal take a value of one ($a_{iik}=1 \forall i$).

In perfect consistency, any two judgments obtained from any two pairwise comparisons that have a common element to be compared, will automatically allow to obtain the third judgment. This means it should hold that $a_{ihk} \times a_{hjk} = a_{ijk}$ for all i, j and h ($i, j, h \in M / i, j, h \in N / i, j, h \in S$). This condition implies that values given for pairwise comparisons represent directly the relative importance by a perfectly rational individual: $a_{ijk} = w_{ik}/w_{jk}$ for all i and j . Therefore, in this case the previous matrix can also be expressed in relative importance terms as follows:

$$S_k = \begin{bmatrix} \frac{w_{1k}}{w_{1k}} & \frac{w_{1k}}{w_{2k}} & \dots & \frac{w_{1k}}{w_{Nk}} \\ \frac{w_{1k}}{w_{1k}} & \frac{w_{2k}}{w_{2k}} & \dots & \frac{w_{Nk}}{w_{2k}} \\ \frac{w_{2k}}{w_{1k}} & \frac{w_{2k}}{w_{2k}} & \dots & \frac{w_{Nk}}{w_{2k}} \\ \dots & \dots & \frac{w_{ik}}{w_{jk}} & \dots \\ \frac{w_{Nk}}{w_{1k}} & \frac{w_{Nk}}{w_{2k}} & \dots & \frac{w_{Nk}}{w_{Nk}} \end{bmatrix} \quad (2)$$

Under such circumstances, K weights (w_{Mk}) for each attribute, for each level (w_{Nk}) and for each product (w_{Sk}) can be easily estimated from the $M \times (M-1)/2$, $N \times (N-1)/2$ and $S \times (S-1)/2$ values for a_{ijk} , respectively. Therefore, in the case of perfect consistency it should hold the verification that: $S_k \times \mathbf{W} = M \times \mathbf{W}$ (for attributes), $S_k \times \mathbf{W} = N \times \mathbf{W}$ (for levels) and $S_k \times \mathbf{W} = S \times \mathbf{W}$ (for products), where \mathbf{W} is a column vector in each case ($\mathbf{W} = [w_1, \dots, w_{m/n/s}]$). However, in surveys it is usual to obtain some degree of inconsistency because the personal subjectivity plays an important role in the pairwise comparison. Therefore, the original verification can be redefined to: $S_k \times \mathbf{W} = \lambda_{\max} \times \mathbf{W}$, where λ_{\max} is the maximum eigenvalue of matrix S_k that is determined by $\lambda_{\max} = \sum_i \sum_j \hat{a}_{ijk} \hat{w}_{ik}$ where the quantity $\lambda_{\max} - M$ (attribute), $\lambda_{\max} - N$ (levels) and $\lambda_{\max} - S$ (product) is an indicator about the degree of inconsistency within the S_k . In this context, the Consistency Index (CI) can be defined as $CI = \frac{\lambda_{\max} - M}{M-1}$ (for attributes), $CI = \frac{\lambda_{\max} - N}{N-1}$ (for levels) and $CI = \frac{\lambda_{\max} - S}{S-1}$ (for products). The Consistency Ratio (CR) then is defined (Saaty, 1980) as $CR = CI/RI$ 4

Values of $CR \leq 0.1$ are acceptable.

The Row Geometric Mean (RGM) prioritization method (Saaty, 1980) is applied as a valid procedure to estimate the real weights. Using this approach, weights assigned by the subject to each attribute and level are obtained using the following expression:

$$w_{ik} = \sqrt[M, N, S]{\prod_{i=1}^{i=M, N, S} a_{ijk}} \quad \forall i, k \quad (3)$$

From the individual weights (w_{ik}) we need to aggregate the values across subjects to obtain a synthesis of priorities (w_i) for the whole sample. The aggregation process is carried out following Forman and Peniwati (1998), who consider that the most suitable method for aggregating individual weights (w_{ik}) in a social collective decision-making context is that of the geometric mean. Once the weights are estimated, the Kolmogorov-Smirnov test is applied to test for normality of the distribution. If the normality do not held, the Wilcoxon non-

parametric test is used to test for differences between weights, otherwise the ANOVA test is applied.

To summarize the application of the AHP approach to analyse the consumers' acceptance for the three types of eggs, an example of the pairwise comparisons matrix construction, the data collection and the relative importance estimation are presented in the complementary data file provided in the following link: [Data collection and AHP estimation \(http://dom.cat/w73\)](http://dom.cat/w73).

3. Results and discussion

3.1. Relative importance of egg attributes in purchasing decisions

Results (Figure 1) showed that the egg type and price had similar and higher importance than the origin, which had higher importance than the egg size in purchasing decisions. The Wilcoxon non-parametric test indicated that the egg type and price did not differ between them, while the origin and size of eggs differed from the other attributes.

Focusing on the levels of the attributes, for the egg type, consumers showed a preference for the free-range type followed by the enriched with n-3 and conventional eggs. As in the case of the attributes, the Wilcoxon test showed that the differences were statistically significant between the free-range and the other types of eggs. However, revealed data in Spain have shown that consumers purchase conventional eggs most frequently (KANTAR, 2012). To better understand these results, it is relevant to take into account the price importance in the purchasing decisions of eggs. The divergence between the stated and revealed preferences in this case is likely to be associated with the price effect between both types of eggs. Statistical data regarding food price in Spain showed that on average the free-range eggs are at least two times more expensive than the conventional ones (Mesías *et al*, 2011), bringing consumers to choose the conventional eggs over other types of eggs.

Regarding the preferences for egg size, results confirmed what we expected. Consumers prefer medium and big egg sizes compared to the small size. The Wilcoxon test showed statistical difference between the small size and the other egg sizes. These results are in accordance to the results obtained by Mesías *et al.*, (2011) where the highest utility (most preferred) of the attributes was for the extra-large size egg (>73 g) against the standard size (53–73 g). Finally, analysing the origin attribute and levels, results agreed with literature data showing a preference for the local origin of eggs for Spanish consumers (Gracia *et al.*, 2013), similar to other food products such as beef (Realini *et al.*, 2014). Thus, consumers preferred the local origin followed by the regional origin, and finally the other Spanish regions. This preference pattern is especially pronounced in Catalonia where the feeling of belonging and the value of locality is rooted in the society in general.

3.2. Hedonic evaluation of egg attributes: The AHP and 9-point scale results

The results of comparing the three egg types according to the selected sensory attributes using the AHP are shown in Figure 2. For the typical egg odour, results showed that the conventional eggs received the highest weight, which means that it had the best score on this attribute than the other egg types. However, the statistical Wilcoxon test showed no odour differences between the conventional and the free-range eggs, which had higher odour scores than the n-3 enriched eggs. These results reflect consumers' unfamiliarity with the odour of the n-3 enriched eggs, which is probably associated to its low frequency of consumption as well as the possible oxidation and subsequent development of off-odours and off-flavours as previously reported in this type of eggs. Parpinello *et al.* (2006) indicated that the off-flavours and off-odours that are usually present in this type of enriched eggs are considered to be a major undesirable side-effect when incorporating high n-3 levels in diets fed to hens.

Regarding the yolk colour attribute, results showed that the conventional eggs had the most typical yolk colour score followed by the free-range and enriched with n-3 eggs. Results showed statistical differences between conventional eggs and both free-range and enriched eggs, which were not significantly different. These results reflect consumers' habits towards the familiar yolk colour they face when consuming conventional eggs. Finally, for the flavour attribute, results indicated that the conventional and the free-range eggs had similar and higher scores than the n-3 enriched eggs. Flavour scores were significantly lower for the enriched eggs with n-3 than the other egg types in agreement with results reported in literature. Karahadian and Lindsay (1989) indicated that the enrichment with n-3 may cause off-flavours in eggs, mainly due to the oxidative damage of yolk lipids which may affect the sensorial quality of eggs (Caston *et al.*, 1994).

Results of the sensory egg valuation using the 9-point hedonic scale are shown in Table 4. Analysing the odour attribute, results show that conventional eggs had higher typical odour score than free-range and n-3 enriched eggs, however, non-significant differences were found among the three types of eggs for the odour attribute. In contrast, results from the AHP approach (Figure 2) showed significant differences between conventional and free-range eggs and the n-3 enriched eggs. This discrepancy may show the capacity of the AHP, and thus the comparative technique, to better detect differences in the odour attribute between the different egg types in the hedonic evaluation in comparison to the 9-point hedonic scale in our exploratory study.

Regarding the yolk colour attribute, significant differences using the 9-point scale were found among the different egg types (Table 4). As expected, the yolk colour of the conventional eggs was perceived as a more typical yolk colour, followed by the n-3 enriched eggs and finally the free-range eggs. Yolk colour results are associated to the different feeding regimes, as it is well known that the free-range hens have in general the opportunity to eat

more pigmented foods and the pigment is then transferred to the yolk, conferring its more orange colour. This tendency was also found in the n-3 enriched eggs but with a relatively lower incidence. This is due to some ingredients used for the egg enrichment with n-3, which are natural sources of carotenoids and thus the yolk shows greater pigmentation (Barbosa *et al.*, 2011). Comparing these results with those obtained from the sensory test using AHP regarding the yolk colour attribute, both methods showed higher scores for the conventional eggs compared with the free-range and the n-3 enriched eggs. However, the AHP was not able to detect major differences in the yolk colour between the free-range and n-3 enriched eggs, showing the superiority of the 9-point scale in this case.

For the flavour attribute, results (Table 4) showed that the free-range and the conventional eggs received higher scores with more typical egg flavour than the n-3 enriched eggs. These hedonic results using the 9-point scale are in agreement with those obtained using the AHP technique that also found significant differences between the flavour of the conventional and the free-range eggs and the flavour of the n-3 enriched eggs. Finally, in line with literature data regarding the sensory valuation of enriched eggs with n-3 (Lawlor *et al.*, 2010), results showed that there are still some potential adverse effects on the sensory attributes of enriched eggs that are currently being commercialized in the Catalan market. The global acceptance scores assigned by consumers using the 9-point scale also indicates that the n-3 enriched eggs have a lower sensory rating than the conventional and the free-range eggs.

The lower flavour and global acceptance scores of the enhanced egg with n-3 in comparison to the other egg types, indicate that the production of n-3 enriched eggs negatively affect its sensory hedonic evaluation. The presence of non-typical flavour of egg is considered the major undesirable side effect of substituting conventional with n-3 enriched feed in the hens' diet (Parpinello *et al.*, 2006). This effect might be related to the flaxseed preparation in the hens' feed. Thus, egg producers are advised to carefully prepare and revise

the feeding mixture for laying hens to minimize the negative impact that the enrichment process may have on the sensory properties of eggs, including the use of antioxidants such as the Vitamin E among other approaches as proposed by Leeson *et al.* (1998).

4. Conclusions

Regarding consumers' hedonic evaluation, results showed agreement between the AHP technique and the 9-point scale showing that n-3 enriched eggs had lower flavour acceptance, conventional eggs had higher yolk colour acceptance, and conventional and free-range eggs had similar and higher odour acceptance than the other egg types. The AHP technique detected significant odour differences, while the 9-point scale detected significant yolk colour differences among egg types.

Empirically, the most important cue driving the majority of consumers' egg purchase decisions were the egg type and price, followed by origin and finally the egg size. Consumers showed preference for free-range, medium and big sizes, and local origin of eggs.

The AHP approach seems to be a potential tool to evaluate consumer acceptance and preferences. However, further testing of the technique should be carried out with other food products and using larger sample sizes in order to validate the AHP as a discriminative method adapted to sensory analysis.

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Table 4: Consumer scores for typical odour, typical yolk colour, typical flavour, and global acceptance of the different egg types using a 9-point hedonic scale.

Egg types	Sensory attributes	Average
Regular egg	Typical odour	6.97 ^a
Free-range egg		6.55 ^a
Enriched egg with n-3		6.61 ^a
Regular egg	Typical yolk colour	7.32 ^a
Free-range egg		4.79 ^c
Enriched egg with n-3		5.73 ^b
Regular egg	Typical Flavour	6.87 ^a
Free-range egg		6.89 ^a
Enriched egg with n-3		6.04 ^b
Regular egg	Global acceptance	7.14 ^a
Free-range egg		7.25 ^a
Enriched egg with n-3		6.15 ^b

^{a,b,c}: Differences among participants at 95%.

Table 3: Random index values (RI)

<i>Number of elements, n</i>	1	2	3	4	5	6	7	8	9	10
<i>Random index (RI)</i>	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Table 2: Example of pairwise comparisons for the flavour attribute using the AHP approach

Typical flavour																	
Sample of egg 1 (3 digit number)									Sample of egg 2 (3 digit number)								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Sample of egg 1 (3 digit number)									Sample of egg 3 (3 digit number)								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Sample of egg 2 (3 digit number)									Sample of egg 3 (3 digit number)								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Table 1: Example of pairwise comparisons for the attributes considered in consumers' purchasing decisions

Egg type									Egg size								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

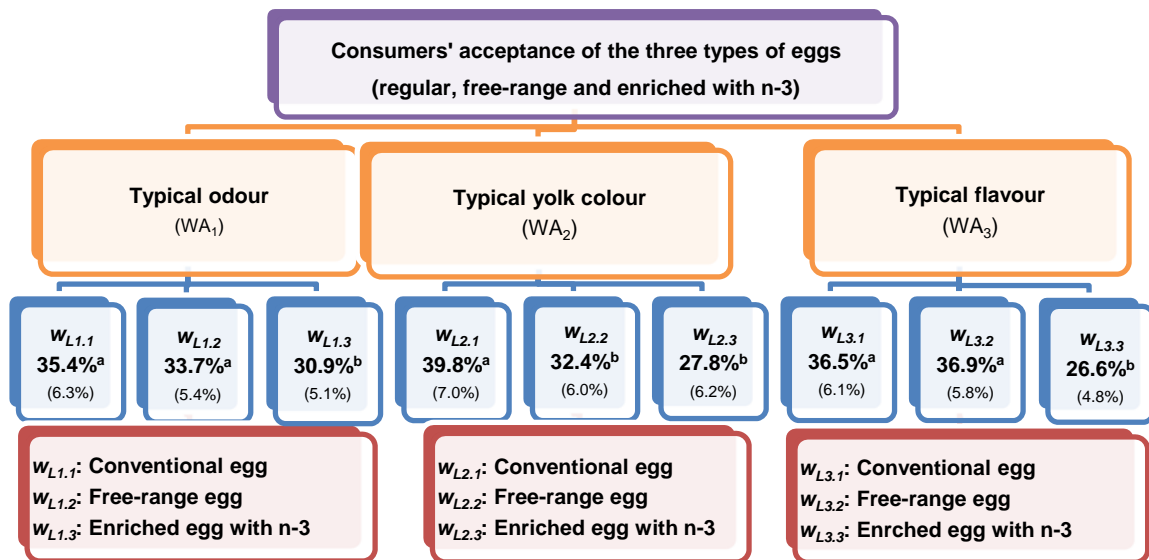
Egg type									Origin								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Egg type									Price								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Egg size									Origin								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

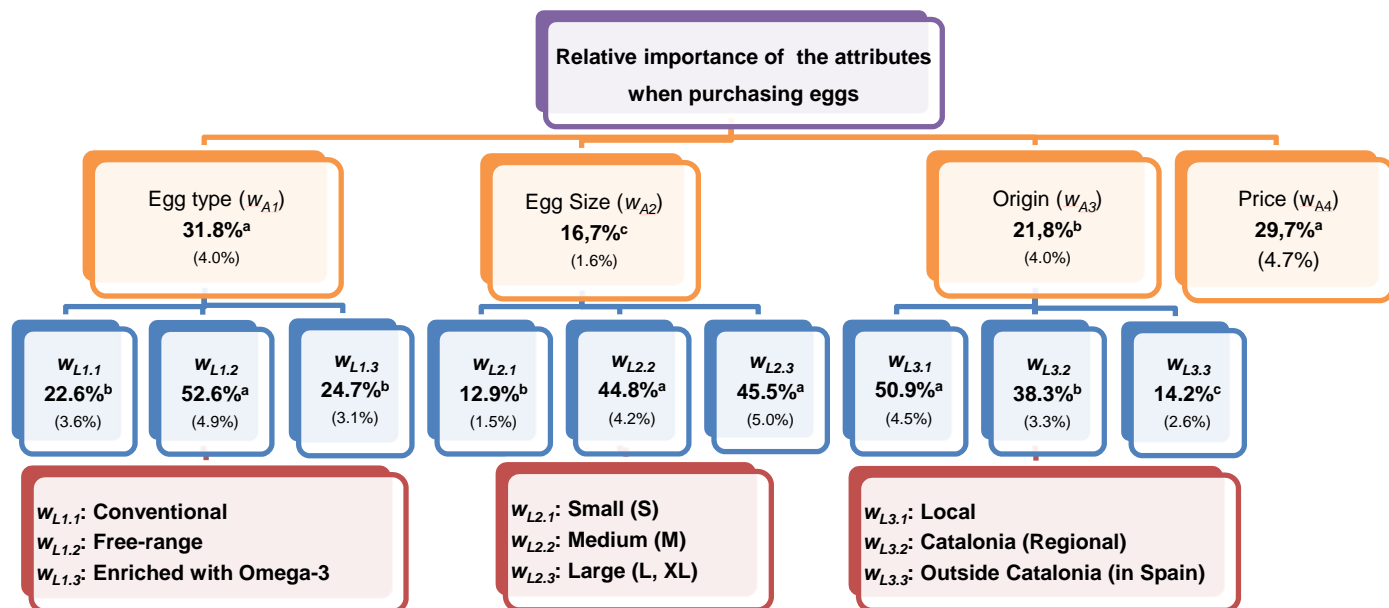
Egg size									Price								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	

Origin									Price								
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	



a,b,c: Differences among participants at 95%. Variances are between brackets.

Figure 2: Results of the hedonic valuation of the different types of eggs using AHP



a,b,c: Differences among attributes and levels at 95%. Variances are between brackets.

Figure 1: Results of the hierarchical structure of the attributes when purchasing eggs.